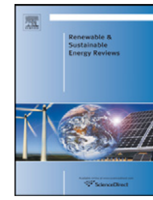
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A review: Renewable energy with absorption chillers in Thailand

Tawatchai Jaruwongwittaya, Guangming Chen *

Institute of Refrigeration and Cryogenics, National Key Laboratory of Clean Energy Utilization, Zhejiang University, 38 Zheda Road, Hangzhou, Zhejiang 310027, PR China

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ABSTRACT

The aim of this paper is to review the energy situation, renewable energy potential and absorption chiller system in Thailand. The renewable energy which will be used in low temperature applications, under the consideration of low operating cost, high availability and non-polluted emission such as solar energy was discussed. Solar energy can be used as power sources for cooling systems, especially for the absorption chiller. Thailand is located in the area where the solar intensity is very high and thus solar energy can be used as power sources. The absorption chiller using water/lithium bromide is the most appropriate for the solar applications. This system, however, is not widely used in Thailand due to its complexity, high toxicity caused by leakage and high initial cost. The utilization of absorption chiller may increase if more researches focus on the development of this cooling system, which is driven by solar energy. This may results in a substantial decrease in electricity consumption.

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1. Introduction

The energy consumption for the industry, agriculture, commerce and residence in many countries has been increasing recently, which leads to the increase in the demand of alternative energy. Fossil fuel like fuel oil and liquefied petroleum gas is commonly used today. Both kinds of fuels are used to generate power for equipment and machines. It was predicted that at the current fuel consumption rate, the fossil fuel will be used up within 50 years or less if the consumption rate is greater than that of the present. Therefore, alternation or renewable energy, e.g., solar energy, hydro energy, wind energy, geothermal energy, biomass and other energy resources, is of interest of several countries to replace the conventional energy.

In the last few decades, the countries around paid more attention to the environmental deterioration which is caused by many factors such as the utilization of fossil fuel and CFCs substances. The product gas of fossil fuel combustion for instance

* Corresponding author. Tel.: +86 571 8795 1680; fax: +86 571 8795 1680.
E-mail address: gmchen@zju.edu.cn (G. Chen).

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Table 1
Estimation of the pollutant emissions from electricity energy consumption.

Years	Carbon dioxide (CO_2)	Carbon monoxide (CO)	Methane (CH_4)	Sulfur dioxide (SO_2)	Nitrogen oxide (NO_x)
	(10^3 tonnes)				
2004	72,637	47	5	199	213
2005	75,956	52	5	213	224
2006	75,839	53	5	231	227
2007	82,087	59	6	359	258
2008	83,308	60	6	393	264

water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur dioxide (SO_2) in the atmosphere can absorb the radiations, which leads to an increase in global warming. In addition, the gases from some industries such as chlorofluorocarbons (CFCs), perfluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6) also cause the increase in global warming but more serious. The phenomenon that the gases which trap infrared radiation act as the glass in a greenhouse is defined by the terms greenhouse gas (GHGs) and the effect caused by these gases is termed as global warming potential (GWP).

These GHGs perform as a blanket for the thermal radiation from the surface of the earth, which results in higher mean global temperature. It can be concluded that the more GHGs have been produced, the higher the rate of increment of the mean global temperature. Recently, the department of alternative energy development and efficiency, ministry of energy estimated the amount of pollutant emission from electricity consumption as shown in Table 1.

Moreover, the CFCs and HCFCs gases, which are used by the conventional vapor compression refrigeration cycle of the air conditioning system not only have high global warming potential (GWP) but also high ozone depleting potential (ODP). These effects, however, can be remedied by choosing the environmental friendly air conditioning system like water/lithium bromide (H_2O/LiBr) absorption chiller.

An important advantage of the absorption chiller is that it can be driven by low grade thermal energy, as a result the alternative energy such as solar energy, geothermal energy, waste heat from industry processes and waste steam can be used as energy sources for this system. Furthermore, the working fluids used in this system are environmental friendly.

2. Energy situation in Thailand

The energy consumption in Thailand during this decade has gradually increased which increased by 2.2% from the year 2007 to 2008 [1]. Commercial energy consumption such as petroleum products, natural gas, coal and its derivatives, and electricity has been increased by 1.5%, whereas renewable energy including wood, charcoal, paddy husk and biogas has been increased by 5.3% since last year.

2.1. Primary energy supply

It is reported that domestic primary energy production in Thailand in the year 2008 was 61,930 ktoe (kilo tonnes of oil equivalent), which was increased by 6.3% since 2007. There are two sources of energy that are likely to be used as commercial energy, which include the indigenous energy production (crude oil, natural gas, condensate, lignite and electricity generated from hydro power, geothermal, solar cell, and wind) and alternative or renewable energy. The former is normally used by 67.1% while the later is 32.9%. However, the country also imported 59,386 ktoe of energy in 2008 which was increased 0.8% compared to 2007. This imported energy costs about US$ 35,000 million (1,178,000 million bahts) which mostly for commercial energy.

2.2. Final energy consumption

The total final energy consumption in 2008 was 66,284 ktoe which was increased by 2.2% more than that of 2007. 82% of this total final energy consumption was commercial energy and the rest was renewable energy. The proportion of the final energy consumption of Thailand in 2008 is depicted in Fig. 1.

Data from Fig. 1 demonstrated that petroleum product is consumed maximally (47% or 31,247 ktoe). It was used mainly for transport sector (72.3% of total petroleum products) and the rest was used in agricultural, manufacturing, residential, commercial, construction and mining sectors (11.0%, 8.3%, 5.0%, 2.9% and 0.5%, respectively). Petroleum has been refined mostly in the form of diesel fuel oil (including palm diesel oil: 48.6%), followed by gasoline (including gasohol), LPG, jet fuel, fuel oil, and kerosene (16.9%, 13.4%, 12.3%, 8.8%, and 0.04%, respectively).

The consumption of natural gas was totally 3218 ktoe in 2008, which was increased by 24.1% compared to 2007. Almost all natural gas (78.8%) was used in manufacturing sectors, whereas only 21.2% was used in transport sectors. For coal and its products, the consumption was increased by 13.5% over than that of 2007 and employed mostly in manufacturing sectors. Electricity consumption increased by 2.5% higher than that of 2007, totally 11,632 ktoe. 45% of electricity consumption were employed in manufacturing sectors and 32.5%, 21.4% and 1.2% were, employed in commercial, residential and other sectors, respectively. The total amount of electricity consumption was consumed mainly by air conditioning systems owing to the rapid growth of new buildings. This building has the requirement of air conditioners of approximately 400,000 units per year [2]. In the total consumption of new or renewable energy were 12,261 ktoe, which increased by

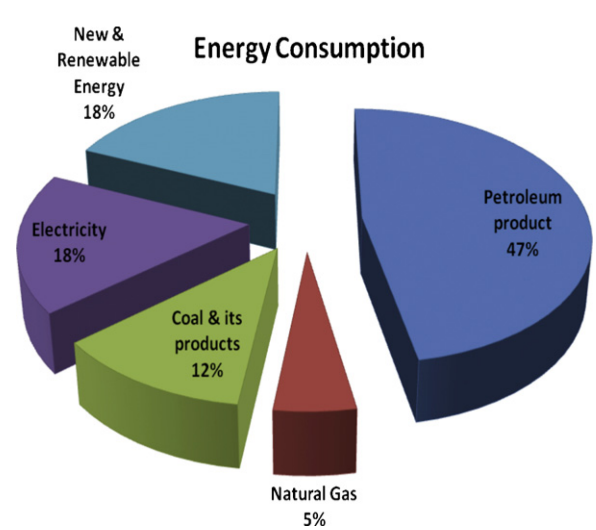


Fig. 1. Energy consumption of Thailand in 2008.

5.3% since 2007. Renewable energy of 51.0% was consumed in manufacturing sector and 49.0% was employed residentially.

3. Absorption chiller for air conditioning systems

Water/lithium bromide (H_2O/LiBr) is working fluid for absorption chiller system, several manufacturers in the U.S. have begun to operate this technology since 1950. Water was used as the refrigerant although it has the disadvantage that the limited temperature of refrigeration is above 0 °C [3]. Absorption machines based on water/lithium bromide are typically configured as water chillers for air conditioning system in large buildings. The available specification of the machines is in the range 10–1500 TR (1 TR = 3.517 kW). The coefficient of performance (COP) of these machines, defined by the ratio between the refrigeration capacity and the driving heat input, varies over the range $0.7 < \mathrm{COP} < 1.3$ depending on the cycle configuration and the temperature of driven heat. The reputations of this kind of machines are stable in operation and reliable in service.

3.1. Configuration of H_2O/LiBr absorption chiller

3.1.1. Single-effect

For a single-effect, absorption cycle using water/lithium bromide as working fluid may be the simplest system of absorption technology. Schematic of a single-effect absorption cycle is shown in Fig. 2. As seen from Fig. 2, the cycle consists of four major components, i.e., a generator, a condenser, an evaporator and an absorber. These components are divided into 3 parts by one internal heat exchanger and two flow restrictors (valve and pump). The energy transfer between the cycle and surrounding is occurred in the four major components and the pump where the direction of these energy transfers is indicated by the arrowheads.

3.1.2. Double-effect

Although it is difficult to compare conventional vapor compression refrigeration systems with the single-effect technology at a highly economical condition due to the relative low COP of single-effect technology, the single-effect absorption cycle can operate economically at low temperature of waste heat applications owing to no cost expense for energy input. For higher temperature of waste heat applications, the solution is proposed which is so-called double-effect technology. The COP of the double-effect technology is much higher than that of the single-effect, which is ranged between 1.0 and 1.3. The double-effect cycle is made by adding high and low heat exchangers between generator and absorber of the single-effect cycle. The generator is then divided into two sections: high and low generators. Moreover, the condenser is also divided into two sections, which are high and low condensers to separate the single cycle to double cycle (double solution circuits). An interconnection between two cycles is conducted on low condenser and low generator. The low generator and low condenser of the double-effect technology almost operate at the same conditions of the generator and condenser in a single-effect technology. The heat input in the double-effect technology occurs at much higher temperature than that of the single-effect technology. From this configuration, the availability of the double-effect technology is increased, as a result of higher temperature of input heat can be utilized: thus the COP of the double-effect technology is greater than that of the single-effect technology. In the process of designing a double-effect system, the method of how to connect the solution circuits is one of the major factors. Normally, parallel and serial flows of refrigerant are the basic structures of this technology. Fig. 3 shows the parallel flow of the double-effect technology that the quantity of solution mass fraction which flows across both of generators is identical.

Two different serial flows of the double-effect absorption cycle are shown in Figs. 4 and 5. The main difference between two

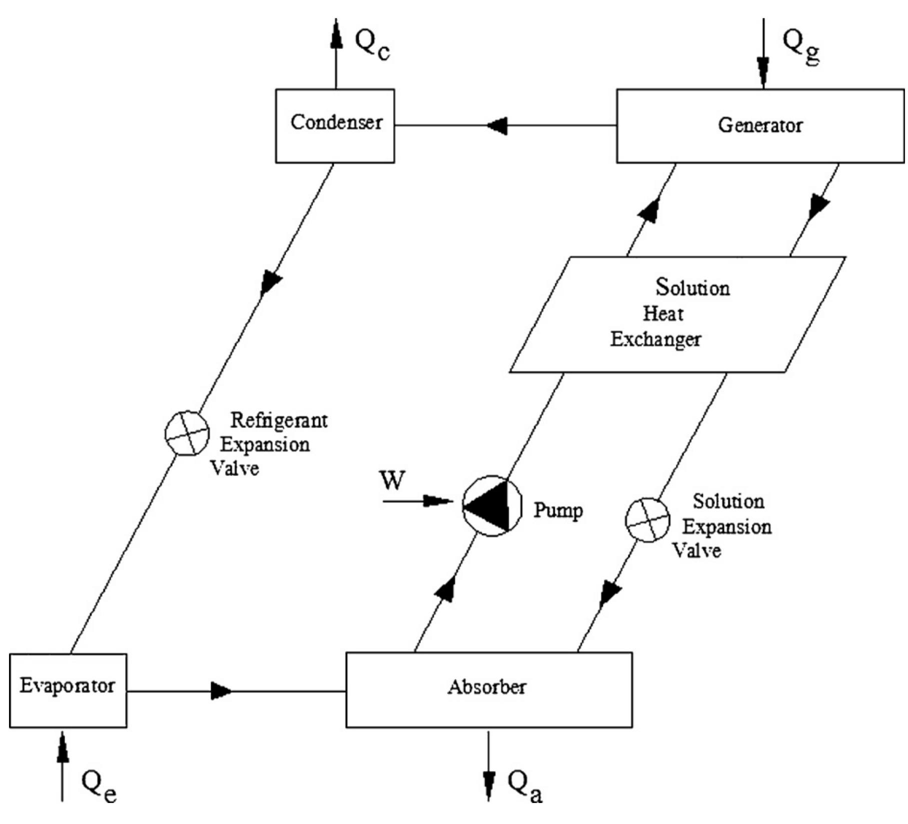


Fig. 2. Schematic diagram of a single-effect absorption cycle.

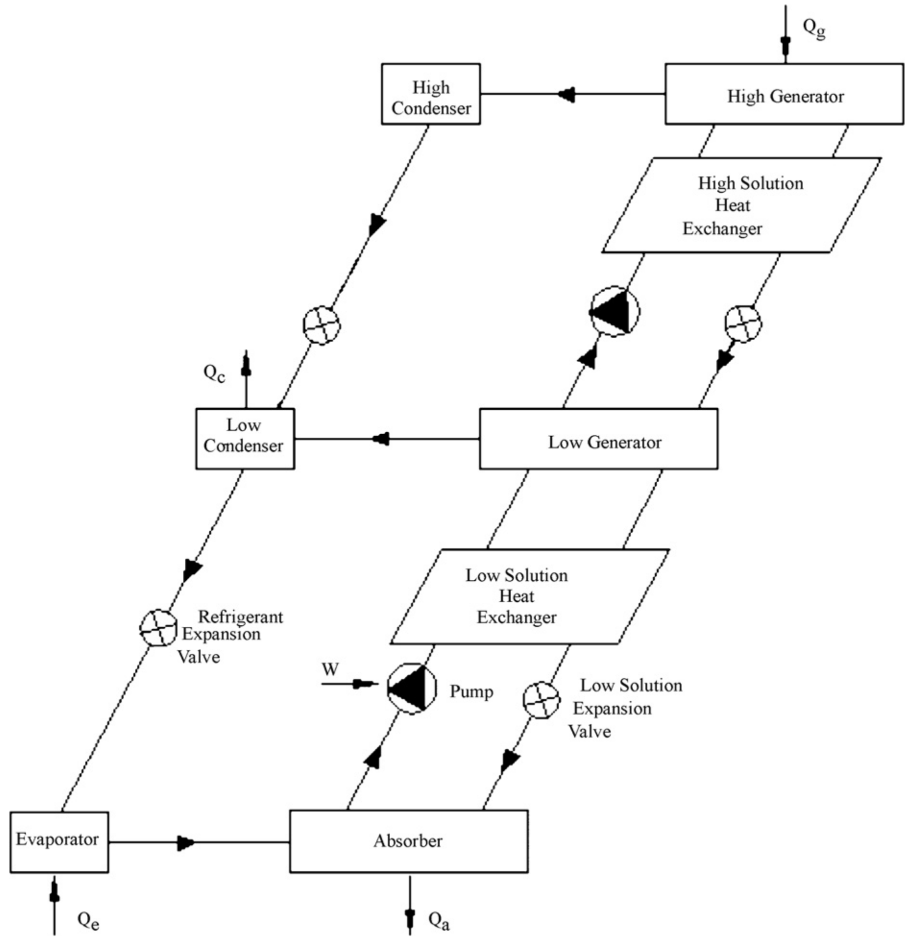


Fig. 3. Schematic diagram of parallel flow of double-effect absorption cycle.

configurations is the number of pumps, which are installed in the cycle. Three and four pumps are installed in the cycles as shown in Figs. 4 and 5, respectively. The solution in Fig. 4 is first pumped to the high generator and then fed to the low generator whereas the reverse is found in the case of the solution in Fig. 5. In both cases, the performance of internal heat exchange process between the high condenser and the low generator are controlled by the temperature. Therefore, temperature of the high condenser must be high enough to provide a driving potential in order to transfer heat to the low generator.

3.2. Simulation and experiment of H_2O/LiBr absorption chiller

Casals [4] has discussed the peculiarities of solar absorption systems. The author concluded that there is a need for more detailed evaluation of this system in order to design them and evaluate their performances properly. A detailed TRNSYS dynamical simulation of some of the first commercial solar heating and cooling installations recently implemented in Spain and was analyzed their perspectives in comparison with other solar cooling options were reported from his experiences. Assilzadeh et al. [5] proposed a model and performed simulation of the absorption solar cooling system using TRNSYS program in order to design for Malaysia and similar tropical regions. A single-effect unit of the H_2O/LiBr absorption air conditioner based on Arkla model WF-36 was employed in their work. They presented that the system was in phase with the weather, i.e., the cooling demand is large during periods that the solar radiation is high. To achieve continuous operation and increase the reliability of the system, a 0.8 m^3 hot water storage tank was essential. From the result, they suggested that the optimum system for Malaysia's climate for a 3.5 kW system consisted of 35 m^2 evacuated tubes solar collector sloped at 20°. Syed et al. [6] reported novel experimental results derived through field testing of a part load solar energized cooling system for typical Spanish houses in Madrid during the summer period of 2003. To drive a single-effect H_2O/LiBr absorption chiller of 35 kW nominal cooling capacity, solar hot water was delivered by means of a 49.9 m^2 array of flat-plate collectors. They found that the measured maximum instantaneous, daily average and period average COP were 0.60 (at maximum capacity), 0.42 and 0.34, respectively, and recommended that the best operation of this technology should be work in dry and hot climatic conditions where large daily variations in relative humidity and dry bulb temperature prevail. Rodríguez et al. [7] investigated the evaluation of alternative lower impact air conditioning technology on solar absorption cooling carried out by Universidad Carlos III de Madrid (UC3M). The experimental facility is based on an on Campus field of 50 m^2 flat-plate solar collectors driving a single-effect commercial H_2O/LiBr absorption machine through a hot water storage tank. Experimental operating parameters have been recorded during 2004 summer season. They showed that cooling power reaches 6–10 kW, with a generator driving power input of 10–15 kW, achieving a mean cooling period of 6.5 h of complete solar autonomy on a seasonal average day. Li and Sumathy [8] performed experimentally a solar powered air conditioning system at the University of Hong Kong. A high performance flat-plate collector of area 38 m^2, a hot water storage tank of 2.75 m^3 in volume, and a 4.7 kW nominal cooling capacity H_2O/LiBr absorp-

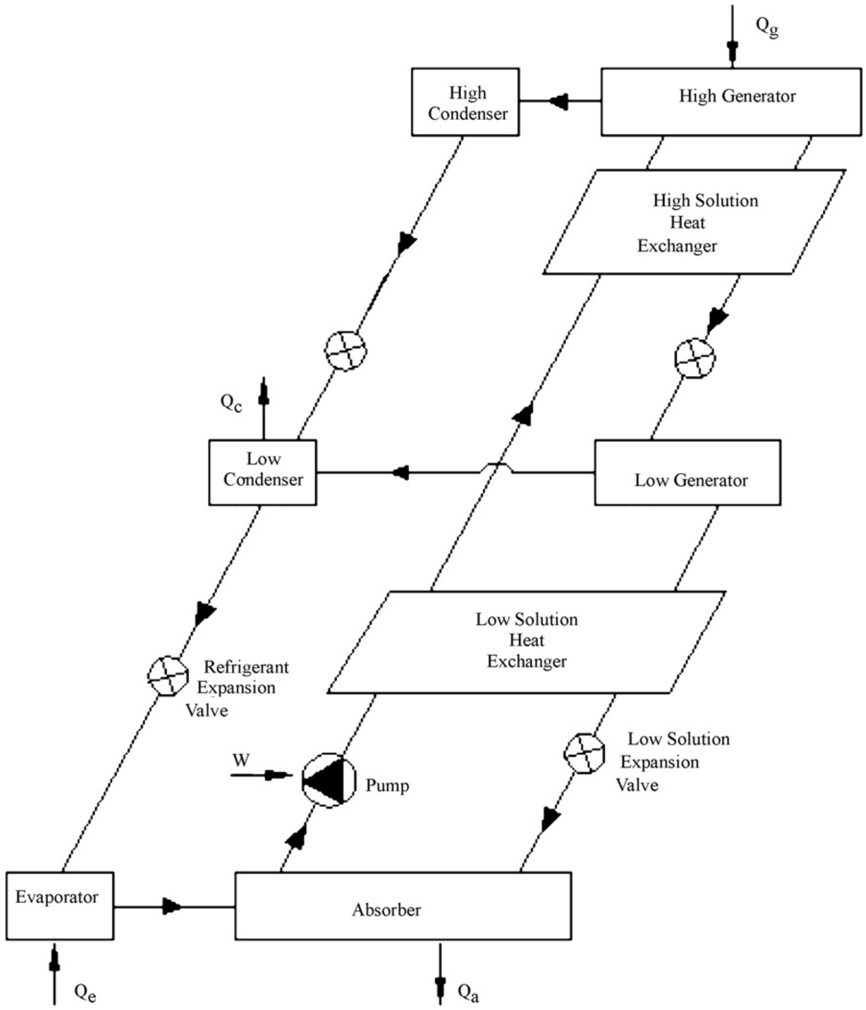


Fig. 4. Schematic diagram of series flow of double-effect absorption cycle (solution to high temperature).

tion chiller were employed in this system. They reported that a total solar cooling COP of about 0.07, which is about 15% higher than that with traditional whole tank mode, was obtained. The simulation of a solar single-effect H_2O/LiBr absorption cooling system in Ahwaz, Iran had been modeled by Mazloumi et al. [9]. To absorb solar energy, a horizontal N–S parabolic trough collector was built and then stored in an insulated thermal storage tank. The system was designed to supply the cooling load of a typical house where the cooling load peak is about 17.5 kW, which occurs in July. They presented that the collector mass flow rate has a negligible effect on the minimum required collector area, which was about 57.6 m^2 and the cooling loads should supplied for the sunshine hours of the design day for July, but it has a significant effect on the optimum capacity of the storage tank. From mentioned studies, most solar cooling systems are based on water-cooled single-effect absorption chillers. Nevertheless, an air-cooled H_2O/LiBr absorption chiller has been investigated theoretically by Kim and Ferreira [10] to develop the performance of this chiller system which is combined with low cost flat solar collectors for solar air conditioning in hot and dry regions. The danger of LiBr crystallization for air-cooled H_2O/LiBr absorption chillers system is less than for commercially available water-cooled one even in extremely hot ambient conditions because the cycle works with dilute H_2O/LiBr solutions. They reported that the chillers would release chilled water around 7 °C with a COP of 0.37 from 90 °C hot water under 35 °C ambient condition. Compared with the directly air-cooled chiller, the indirectly air-cooled chiller presented a cooling power performance reduction of about 30%.

3.3. Absorption chiller applications in Thailand

Co-generation system is utilized for producing electricity and chilled water in Suwarnabhumi international airport Thailand as shown in Fig. 6. The main function of this plant is to generate electricity by the hot gas obtained from combustion of natural gas into gas turbine engine to drive two generators of 40 MW [11]. The exhaust gases leave from gas turbine engine into heat recovery steam generator (HRSG) in order to generate high pressure steam into steam turbine for driving 13.6 MW generator. The waste steam after being used in steam turbine which is still with high temperature passes through eight single-effect absorption chillers by using Lithium bromide and water (H_2O/LiBr) as working fluid pairs. The total cooling capacity is 16,800 TR (2100 TR each). It can produce chilled water at temperature of 5–7 °C and supply for passenger buildings, hotels and other buildings within the airport. Pongtornkulpanich et al. [12] reported their experiments of a solar-driven 10-TR H_2O/LiBr VAC cooling system installed at the School of Renewable Energy Technology (SERT), Naresuan University, Phitsanulok, Thailand. A schematic diagram of the major components of this system is represented in Fig. 7. Hot water is used to drive the absorption chiller which produces chilled water. To make sure a stable supply of hot water, thermal

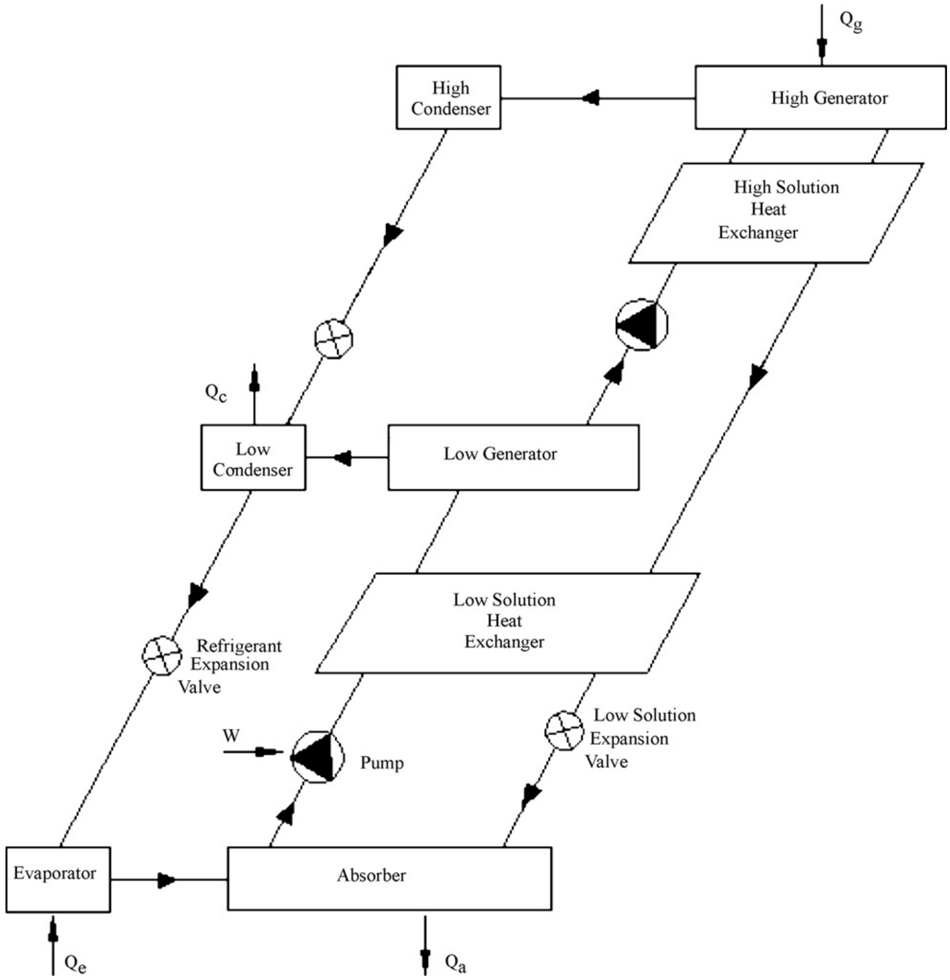


Fig. 5. Schematic diagram of series flow of double-effect absorption cycle (solution to low generator).

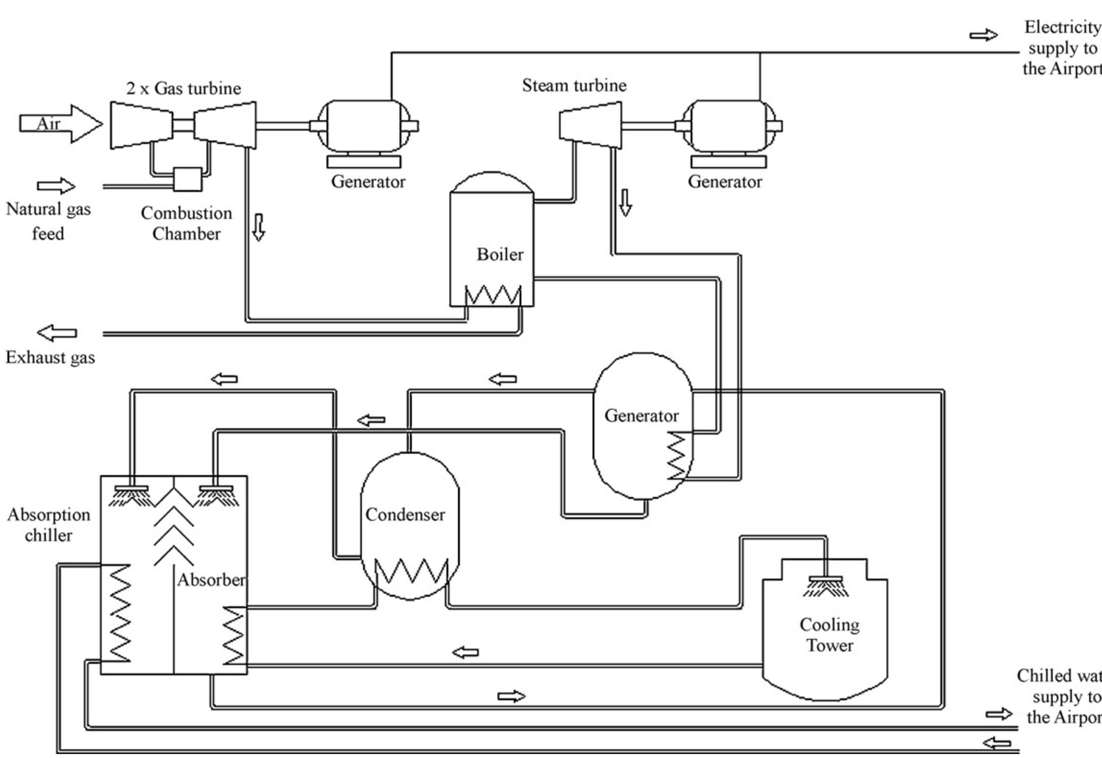


Fig. 6. Schematic diagram of the co-generation system in Suwarnabhumi international airport.

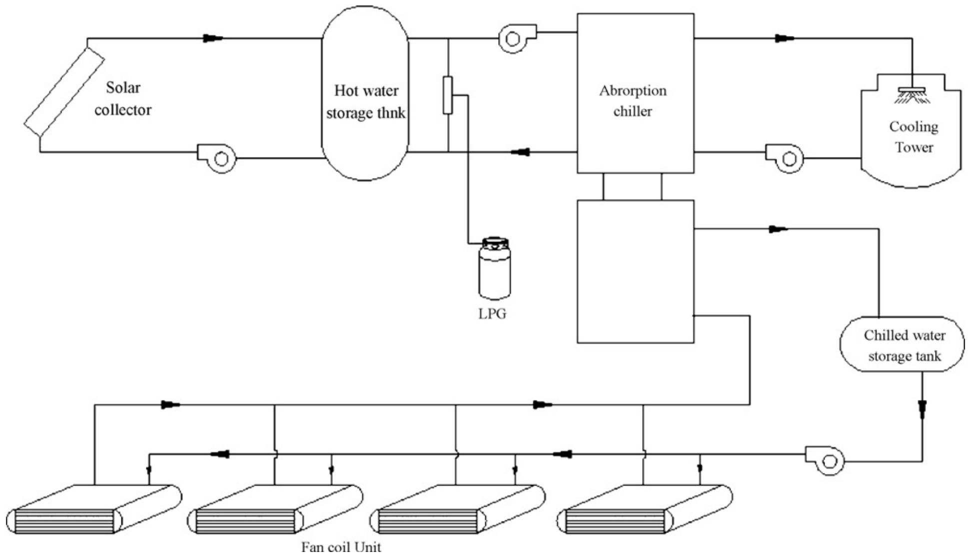


Fig. 7. Schematic diagram of solar-driven single-effect absorption chiller.

Table 2
Comparison of energy consumption rate of air conditioning systems.

Description	Absorption chiller	Vapor compression
Total cooling capacity	280 TR	280 TR.
Main energy input	8 bar, sat. steam (heat recover)	Electricity
Electricity energy consumption	114.82 kWh/Y/TR.	7996.63 kWh/Y/TR.
Total operating expense	9.52 US$/Y/TR.	662.92 US$/Y/TR.

Note: electricity change rate of 0.0829 US$/kWh.

Table 3
Potential of oil crops for bio-diesel production [15].

Oil crop	Annual yield (tonnes/ha)	Oil extraction rate (%)	Annual bio-diesel yield (l/ha)
Palm oil	17,544	18.6	3527
Soy bean	1,438	22.9	350
Peanut	1,575	20.3	346
Sesame	619	24.2	162
Castor bean	688	40.7	302
Jatropha	5,000–1,875	25.0	1,355

buffering between solar collector and chiller was carried out by a 400 L storage tank. The chiller requires a hot water temperature between 70 and 95 °C. The collector arrays, which are the main heat source for the chiller, were mounted on the roof of the testing building. It consisted of 30 evacuated tube plates arranged in 5 series of 6 units. Whenever the temperature of the water in the storage tank drops below 70 °C, an LPG-fired backup heating unit is activated. They reported that the 72 m^2 evacuated tube solar collectors delivered an 81% of yearly average total energy while the remaining 19% of thermal energy required by the chillers was supplied by a LPG-fired backup heating unit. The Electricity Generating Authority of Thailand (EGAT) has compared energy consumption rate of air conditioning system with H_2O/LiBr absorption chiller and vapor compression system which is shown in Table 2 [13]. As can be seen from Table 2, the absorption chiller can save electricity up to 7881.81 kWh/Y/TR, which accounted 98.56% of total electricity consumption of vapor compression system. From this profit, it can be obtained the compensation in both of fuel oil and diesel to generate electricity, namely 880.91 US$/Y/TR of fuel oil and 2153.59 US$/Y/TR of diesel.

4. Renewable energy potential in Thailand

4.1. Solar energy

The location of Thailand is in Southeast Asia at latitude 5°37′–20°27′N and longitude 97°21′–105°37′E. In 2008, the weather of Thailand was reported by meteorology was 76%RH and average maximum temperature of 32.4 °C. The Department of Energy Development and Promotion and the Faculty of Science of Silpakorn University studied the solar energy potential in Thailand (1999) [14]. They found that the solar radiation was influenced by the northeast and the southeast monsoon and it had the highest intensity value of 20–24 MJ/m^2 per day on April and May, and the mean solar energy potential per year was 18.2 MJ/m^2 per day.

4.2. Hydro energy

Since 1964, hydro power has been developed for power generation. In 2008, the electricity totalized 1533 ktoe was generated from 17 dams nationwide.

4.3. Bio-diesel

Potential raw materials for bio-diesel production in Thailand are vegetable oil for instance palm oil, coconut oil, soy bean oil, ground nut oil, castor oil, sesame oil, sunflower oil and jatropha oil. The palm oil and jatropha are the two main oilseed crops in Thailand. The potential of oil crops for bio-diesel production are summarized in Table 3.

5. Conclusions

The ratio of electrical energy required for providing air conditioning to the total consumption of electricity is nearly half or even more in Thailand. Among the alternative energy sources, solar energy is expected suitable sources owing to their advantages which can be used in low temperature applications, i.e., low operation cost, rapid availability and non-polluted emission. Solar energy systems are, therefore, promising means for reducing the consumption of non-renewable energy sources.

Average yearly solar energy potential in Thailand is 18.2 MJ/m^2/day, which is quite high in intensity; as a result, the solar energy can be used in the water/lithium bromide absorption chillers. The power gained from the solar energy is used in the generator and the cost of

solar collectors is low. However, it is rarely found the absorption chillers installed in the small residences due to the large size of the absorption unit. It is possible to produce small size absorption air conditioning systems for residential buildings using solar energy. This may lead to an increase in use of absorption chillers in Thailand. More research on this system should be conducted in the near future.

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